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Volume 8 July, 1922 *Number 7*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

"Modern Oil Burning"

(a) Burners and Equipment

(b) Economic Advantages of Fuel Oil

PUBLISHED MONTHLY BY
THE TEXAS COMPANY, U.S.A.
TEXACO PETROLEUM PRODUCTS

The Present

conditions in the Coal Industry and their natural consequences have accelerated the growing interest in the use of fuel oil.

Therefore we have deviated somewhat from our regular program in order to publish some data and information on "The Modern Fuel" and methods of its combustion.

Although this article fills an entire issue of our Magazine, the subject is by no means fully dealt with, nor could it be in a book many times the size of this.

Despite the limitations of space, our article touches on most of the important points and after reading it, should you want more specific information on any phase of fuel oil combustion, you will find us glad to answer any question fully and freely.

Any of our readers who are considering changing over to fuel oil, will do well to take advantage of the experience The Texas Company has gained in observing fuel oil installations of various kinds in all parts of the country.—This is yours for the asking.

THE TEXAS COMPANY, U. S. A.

Texaco Petroleum Products

Dept. H, 17 Battery Place, New York City

LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

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Modern Oil Burning

THE demand for fuel oil is constantly increasing and this growth may be attributed to a variety of factors, perhaps the most important of which is an increasing appreciation of its remarkable suitability for a large number of heating and power purposes. This increased demand for fuel oil may, in some cases, be brought about by an occasional scarcity of coal and the consequent high price, or a shortage of labor, but in most cases, and in particular in the merchant marine the general economic aspects of oil burning are of critical importance. The keenness of competition makes imperative the use of a fuel more flexible and more economical as to space than coal, and oil burning under the best conditions may be the determining factor in the struggle for supremacy between competing shipping interests. Its use at sea has grown so rapidly in recent years that the demands of the U. S. Shipping Board alone in 1921 were about 40 million barrels.

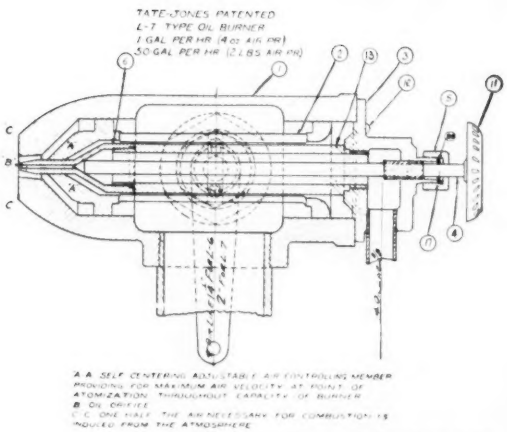
There is some agitation at present to the effect that fuel oil sources will soon be exhausted and that we should conserve oil for possible naval use. While the Navy should always have first call upon fuel oil resources and provision should certainly be made in order to insure that these resources will be available in time of war, it does not appear that there will be an exhaustion for some time to come. In spite of improved methods of making gasoline and lubricating oil there is always a residue that is useful for fuel, and there are many crudes that give little else of value except fuel oil. Until refining methods are able to convert all of this fuel into gasoline or light products, or the internal combustion engine is developed to burn the less refined products, there will be plenty of oil to burn under boilers where such procedure results in increased efficiency and lower expense.

True conservation of fuel resources means the utilization of those fuels which are most economical and produce the least waste. This means, in many cases, fuel oil.

Characteristics

As previously stated, fuel oil is generally a residue from some refining process, though there are many cases where it is not economical to refine the crude, and it is used practically as is. This does not mean that all residues can be burned under boilers. Some residues are so poor in quality as to forbid economical use. Chemical analysis shows that besides compounds of hydrogen and carbon, commercial fuels contain sulphur, nitrogen, oxygen and mineral matter. An average analysis of domestic fuel shows about 84.5% carbon, 12% hydrogen, 1% sulphur, 1.5% nitrogen and oxygen, and 1% moisture. Mexican fuels contain about 4% sulphur. Too high a sulphur content often renders a fuel unsuitable for some purposes, though in many cases oils that apparently can not be used on account of high sulphur content may be satisfactorily burned if proper precautions are taken.

Fuel oil is usually specified by its density, heat value, sulphur content, flash point and viscosity.


TATE-JONES PATENTED
L-7 TYPE OIL BURNER
1 GAL PER HR (4 oz AIR PR)
50 GAL PER HR (2 LBS AIR PR)
A A SELF CENTERING ADJUSTABLE AIR CONTROLLING MEMBER PROVIDING FOR MAXIMUM AIR VELOCITY AT POINT OF ATOMIZATION THROUGHOUT CAPACITY OF BURNER
B OIL ORIFICE
C C ONE HALF THE AIR NECESSARY FOR COMBUSTION IS INDUCED FROM THE ATMOSPHERE

Courtesy of Tate-Jones & Co.

Fig. 1.—Tate-Jones Air Atomizing Burner.

The *density* may be expressed as specific gravity or in Baume degrees. The Baume scale (141.5 Modulus) is used almost exclusively in the trade to state the gravity of oils, and is so graded that 10 stands for the specific gravity of water, or unity. Liquids lighter than water have higher numbers than 10. Consequently, the lighter the oil, the higher the Baume degrees. Boiler fuel oil has a Baume gravity of about 15°, gas oil about 35°, kerosene about 41°, and gasoline about 58°.

The *heat value* of fuel oil is expressed in BTU's per pound.

The *sulphur content* is the percent by weight of sulphur in the oil, and is one of the most important specifications as it determines very often the suitability of an oil for a given purpose.

The *flash point* of an oil is a rough measure of the temperature at which inflammable vapors begin to pass off. It is, consequently, an indication of the fire hazard. A minimum value is generally specified by law, which for fuel oil is usually 150° F. by the Pensky-Martens closed tester. As the flash point depends somewhat on how determined the type of instrument used should be specified.

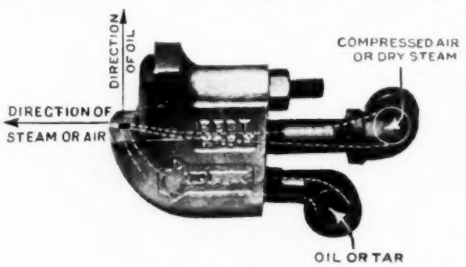
The *viscosity* of an oil is the measure of its internal friction, and is a most important factor in the burning of oil fuel, especially in regard to atomization. Viscosity is measured by various instruments, depending on the locality. In the United States the Saybolt Furol is standard, while in England the Redwood is used, and Germany prefers the Engler. In LUBRICATION for May, 1921, the subject of viscosity was discussed quite fully and a table* was given showing the relationship between the different instruments.

Atomization

To burn oil completely, it must be thoroughly atomized, that is, it must be divided into minute particles so as to expose as much surface to the air as possible. The atomizing device is called a burner.

To atomize an oil, its internal friction or viscosity must be overcome. Viscosity is greatly reduced by heat, which is taken into consideration in the commercial burning of fuel oil by preheating it before admitting it to the burner. The change of viscosity with temperature was discussed in the June, 1921 issue of LUBRICATION and a chart was given for lubricating oils.

It has been found in practice that atomization is appreciably improved by preheating. The preheating temperature in open vessels or in storage tanks under atmospheric pressure should be below the flash point of the oil as given by the closed cup tester. In pipe lines or closed vessels under pressure, the preheating temperature may safely be higher than the flash point. It is often necessary to heat the oil quite high in order to get the requisite fluidity. The limiting factor in this case is the formation of gas in the line, which causes the flame to flicker. In addition to preheat, other agencies are necessary in order to atomize an oil. The methods usually employed to produce atomization are: (1) Air under pressure, (2) Steam, (3) Mechanical breaking up, accompanied by centrifugal action.



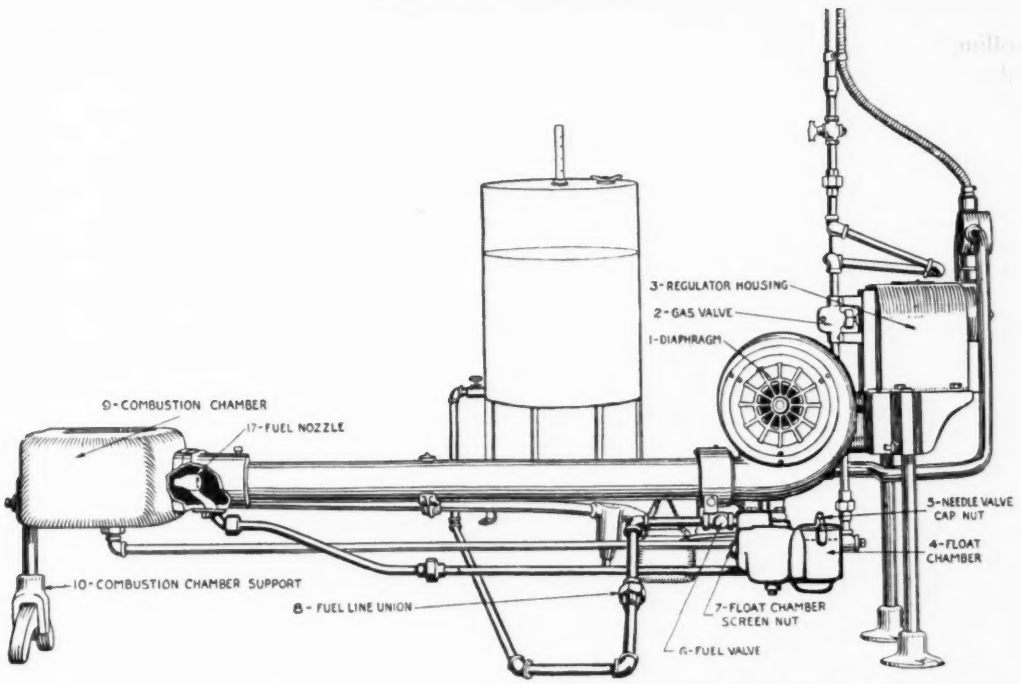
Courtesy of W. N. Best Furnace & Burner Corp.

Fig. 2.—Best Burner. The atomizing agent may be steam or air, and impinges against the oil stream at right angles.

Air Atomizers

When a jet of air is used the burner is called an air atomizer. In house-heating burners, in which light oils of 30 or more degrees Be. are

* Copy of this chart can be obtained by application.



Courtesy of Cornell Utilities Co., Inc.

Fig. 3.—No-Kol House-heating Burner, using kerosene or other light fuel oil. The oil flows by gravity from the storage tank shown to the float chamber. From this point the air supplied by the fan sucks oil from the float chamber and atomizes it at the nozzle, creating a very minute spray which is instantly ignited by the gas pilot and burned completely. The electric motor driving the fan is controlled by a thermostat.

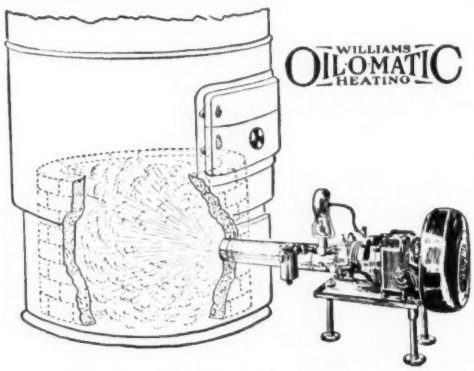
used, a stream of air from a fan or blower is sufficient to atomize the oil satisfactorily. In burners used for firing furnaces or boilers, air under a pressure up to 50 lbs. is necessary, the pressure depending upon the design of burner, and the gravity of the oil used. The atomizing air is not sufficient to burn the oil completely and additional or secondary air is admitted to the combustion chamber through openings around or under the burner. The oil pressure in such burners may vary from 15 to 50 lbs. according to the capacity of the burner and the gravity of the oil. Air for atomizing is used chiefly in burners adapted for house-heating and for oil furnaces, which generally are operated with oils that do not require preheating.

Various methods are used to obtain air atomization. In one type of atomizer, the oil issues through a small central orifice and the air through a thin annular ring, or through small slots, arranged around this orifice. In another type the air impinges against the oil at a sharp angle, thus breaking it up and mixing the particles thoroughly with the air. In still another type, the oil strikes an abutment in the burner; the shattered oil particles are then struck by a powerful jet of steam or air and the mixture blown out of a narrow slot in the burner. Two types of air atomizers are shown in Figs. 1 and 2.

An important adaptation of the air atomizer and one which is attracting increasing attention, is the oil burner for heating residences. Several burners have been placed on the market recently, some using kerosene, others capable of burning oil as heavy as 20° Be. without preheating. They usually operate with electricity, a motor driving a pump and fan. The pump takes the oil from the storage tank and forces it under moderate pressure through the burner. The fan supplies the air for atomization. See Figs. 3 and 4.

The problem of heating homes with fuel oil is somewhat complicated. To use a heavy oil of high viscosity (which would be very desirable because of the low cost) it is necessary to preheat the oil for proper atomization. This can not be done by hot water or steam from the furnace because of the intermittent operation of the latter, hence an auxiliary heating apparatus is necessary. This apparatus would necessarily consist of an oil heater, heated by gas or operated by electricity, and a thermostat to maintain the oil at a fixed temperature by con-

trolling the gas flame or the current. This involves additional expense and complications with greater probability of a breakdown. Successful and continuous operation of an automatic equipment of this nature for oils requiring preheat is doubtful without considerable supervision. The cost of operation, however, would be small compared with coal.



Courtesy of The Fuel Oil Burner Corp.

Fig. 4.—Oil-O-Matic House-heating burner, consisting of thermostat, electric motor, pump, fan and electric spark pilot for igniting oil.

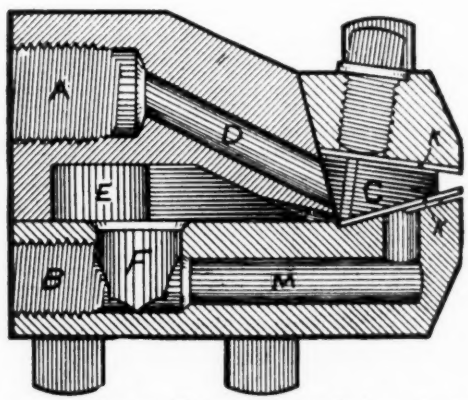
If, on the other hand, a light oil which does not require preheating is considered, only a simple burner equipment is required. This equipment would consist of a buried storage tank of possibly 500 gallons capacity; pipe lines from the tank to the burner, one for supplying oil, the other to return excess oil to the tank—a motor, pump and fan mounted together in a small compact unit, placed in the door of the furnace, and a thermostat nearby operating the motor and controlled by a thermometer located in some convenient place in the house. To ignite the oil, a gas pilot burns constantly in the furnace adjacent to the tip of the burner.

When comparing coal and oil costs it should be remembered that the elimination of the ash nuisance and the coal shovelling operation, the great cleanliness surrounding oil burning and the almost perfect automatic operation of a light oil burner are great advantages in favor of oil, and in many cases would offset even a greater cost over coal burning.

Steam Atomizers

With oils ranging from 11° Be. to about 20° Be. a jet of steam is generally considered to be a better atomizing agent than air. The jet of air has the same average temperature as the surrounding atmosphere. Atomizing steam has a temperature higher than 212° F., depending upon its pressure. It is consequently much hotter than the oil to be atomized.

In the steam atomizing burner, the steam issues in some designs through a horizontal slot directly under the oil slot. A thin fan-shaped jet of oil consequently falls into a flat fan-shaped vapor stream and practically perfect atomization results. In another type, the oil is forced upward through a narrow slot, steam under pressure issues horizontally from an adjacent slot and strikes the oil stream at a right angle, breaking it up into a fine mist. See Fig. 2. In these designs the atomization is done outside the burner orifice. These types are sometimes called outside atomizers. In another type the oil and steam meet inside the burner just before reaching the orifice. These burners are called inside atomizers. See Figs. 5, 6 and 7.



Courtesy of Hammel Oil Burning Equipment Co., Inc.

Fig. 5.—Hammel Burner. A. Oil inlet. B. Steam inlet. C. Mixing or atomizing chamber. D. Oil inlet duct. E. Equalizing steam chamber

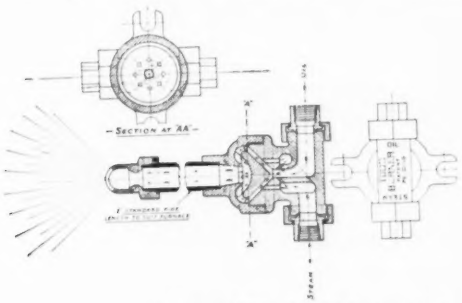
The steam and oil are under moderate pressure which averages 30 lbs. for the oil and somewhat higher for the steam, the actual values depending on the burner design and on operating conditions.

Steam atomizing burners are used to a large extent for firing boilers. The air for combustion is admitted through damper doors and through air spaces in the fire brick floor replacing the grates. In some installations the air is preheated to a considerable degree before it enters the combustion chamber by passing through a furnace of special design. Improved combustion and higher boiler efficiency are claimed for this type of installation.

The steam for atomizing may be as low as 2%

of that generated, or about $\frac{1}{3}$ lb. steam per lb. of oil burned. The amount depends somewhat on the design of the burner but largely on the skill and attention of the operator. The minimum of 2% is difficult to attain and maintain, so that the steam consumption may be a considerable item in the cost of operation.

Various designs have been placed on the market in which an effort is made to reduce the atomizing steam to a minimum. Successful



Courtesy of White Fuel Oil Engineering Corp.
Fig. 6.—Todd Steam Atomizing Burner.

operation has been claimed for these burners and the steam consumption is said to lie between 1% and 2%. In one design the steam passes through fixed orifices of such size that with the maximum steam pressure available, the steam consumption will not exceed a certain amount. In another design, when the desired maximum is exceeded, the flame flickers or is extinguished, thus calling the attention of the operator and requiring a new adjustment.

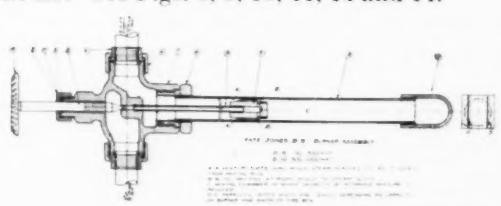
The importance of keeping the consumption of steam for atomizing as low as possible becomes apparent from a little calculation.

A further objection to atomizing with steam comes from marine operation of boiler plants where the difficulty and undesirability of producing fresh water at sea makes its conservation imperative. The steam atomizer is consequently not entirely suitable for the marine service. These objections to the steam atomizing burner have led to the invention of a type of burner in which the use of steam is eliminated altogether. This is the mechanical burner.

The Mechanical Atomizer

In this type of burner the oil is highly preheated and forced at high pressure through the burner. On its way to the orifice it passes through a specially designed tip in which it takes paths which give it a whirling motion when it leaves the burner. The effect of the high preheat and whirling motion causes the oil to break up into exceedingly fine particles, in which condition it mixes thoroughly with the air and burns completely. The temperature of preheat ranges from 200 to 250° F. and the pressure of the oil may be as high as 200 lbs. per square inch.

The tip is the special feature of this burner. It consists of a central chamber with tangential slots leading to it. The pressure drives the oil through these slots at high velocity, and when it enters the chamber it acquires a rapid whirling motion. When it leaves the burner this motion sets up a powerful centrifugal action which throws the finely divided oil particles away from the axis of the burner, and distributes them along a thin conical surface, with its apex at the orifice and exposed on all sides to the air. See Figs. 8, 9, 10, 11, 12 and 14.



Courtesy of Tate-Jones & Co.
Fig. 7.—Tate-Jones Steam Atomizing Burner.

Unlike the steam atomizer which can be operated satisfactorily at varying loads, the ordinary mechanical burner will not atomize efficiently at loads less than about half the designed capacity, if this reduction is brought about by the obvious method of lowering the pump pressure. To change the capacity of the burner and obtain satisfactory operation various methods are used in practice.

In one method, the pump pressure is kept constant and the size of the orifice varied. This necessitates changing burner tips. Where several burners are in use, however, a light, medium or heavy fire to suit the load may be obtained by changing the number of burners instead of changing tips.

In another method, the size of the tangential passages is varied with changing load so as to maintain a practically constant oil velocity. The whirling motion and centrifugal action are thus constant, and efficient atomization is obtained through a considerable range of capacity.

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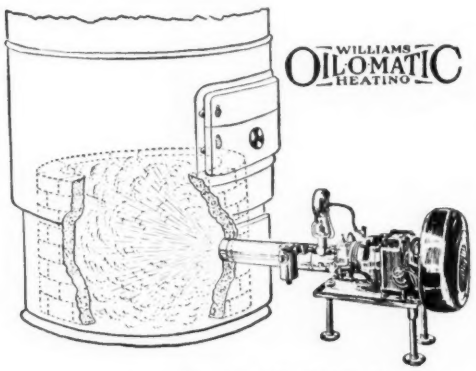

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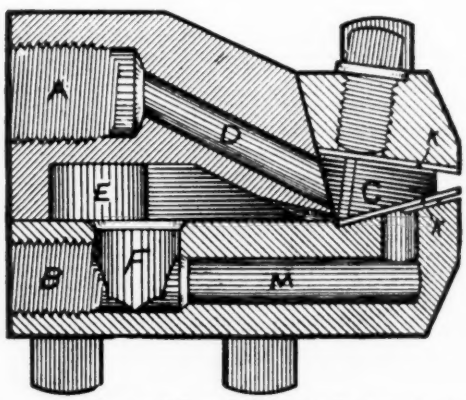

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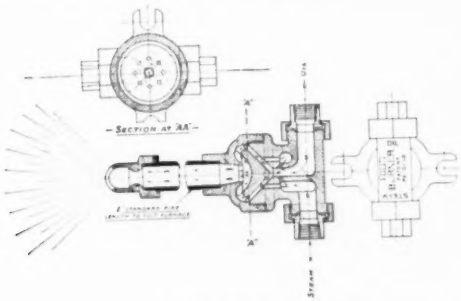

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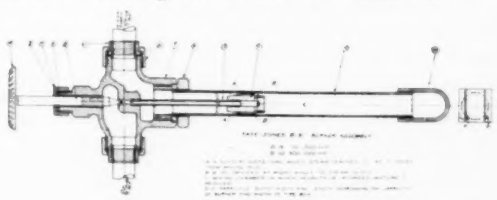

Courtesy of Tate-Jones & Co.
Fig. 7.—Tate-Jones Steam Atomizing Burner.

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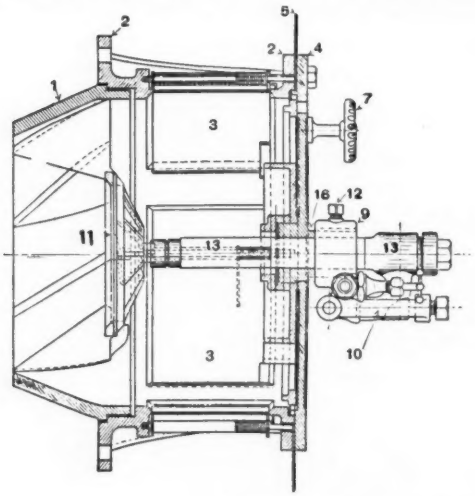
In one method, the pump pressure is kept constant and the size of the orifice varied. This necessitates changing burner tips. Where several burners are in use, however, a light, medium or heavy fire to suit the load may be obtained by changing the number of burners instead of changing tips.

In another method, the size of the tangential passages is varied with changing load so as to maintain a practically constant oil velocity. The whirling motion and centrifugal action are thus constant, and efficient atomization is obtained through a considerable range of capacity.

In a third method the pump pressure and orifice remain constant, but the flow through the orifice is altered by a valve which shunts the proper amount of oil away from the burner and back to the pump suction. See Fig. 9. The whirling motion of the oil in this method is unchanged and the centrifugal action which produces atomization remains at its maximum



Courtesy of The Babcock & Wilcox Co.

Fig. 8.—Babcock & Wilcox Mechanical Atomizing Burner. 1. Conical casting. 2. Register casting. 3. Automatic doors for controlling air supply. 4. Cover plates. 5. Radiator Guard. 7. Handle for rotating air doors. 11. Conical shaped impeller plate for regulating distribution of air at burner nozzle. 13. Mechanical atomizer.

value. The efficiency of the burner is consequently high at practically all loads, and tests have shown that a good spray can be obtained at capacities as low as 10% of the maximum output of the burner.

A complete mechanical burner unit includes a firing front which is a casting of cylindrical or conical shape supporting the burner and containing a register for admitting and controlling the air for combustion. In this type of burner, all the air for combustion is admitted through the register. The register consists of a series of damper doors, mounted around the frame, operated simultaneously by a handle and designed to give the proper amount of entering air an appreciable whirling motion, contrary to the whirling motion of the oil.

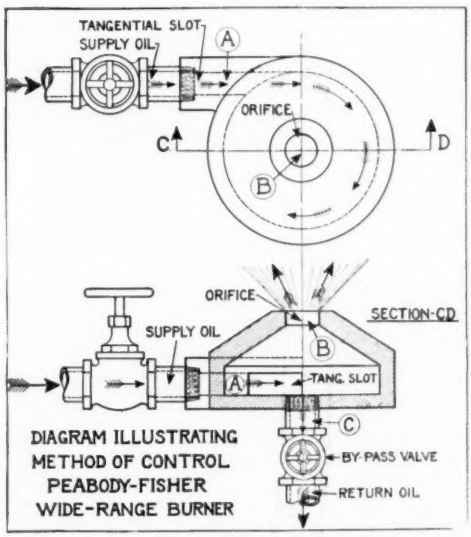
Oil Burning Equipment

A modern oil-burning installation suitable for boiler plants would consist of the following equipment:

Storage Tanks	Pumps and Air Chambers
Strainers	Heaters
Burner Governors	Thermometers
Oil Level Gauges	Necessary Piping
Oil Burners	Pump Governors
Meters	Draft and Pressure gauges

Fittings and Valves

Storage Tanks are made of reinforced concrete or steel. Steel tanks are cylindrical and horizontal or vertical. Horizontal tanks are supported on concrete cradles, vertical tanks on substantial concrete foundations. The regulations governing the size, design and installation of storage tanks vary with different localities. Where oil has been burned for many years, the restrictions are usually mild and the cost of installing tanks moderate. Where oil burning is a recent development, the storage of oil is surrounded by restrictions which in some cases make oil burning assume the characteristics of a desirable but unattainable luxury. All tanks for storing the usual grades of boiler fuel oil are equipped with steam or hot water coils for heat-



Courtesy of Peabody Engineering Corp.

Fig. 9.—Peabody-Fisher Wide Range Mechanical Burner.

ing the oil. The oil is usually heated to 90° or 100° F., which temperature is well below the flash point and gives the oil sufficient fluidity for easy pumping. Storage tanks are vented, installed and equipped with safety devices as required by the regulations governing the locality. On vessels, the main storage tanks are in the double bottoms (the oil in them is kept only warm enough for easy pumping) and an auxiliary storage or settling tank is located near the boilers. In this the temperature is carried

to about 150° to enable moisture or sediment to settle quickly.

Pumps are low or high pressure, electric or steam driven and of the duplex type. Some electric pumps are of triplex type. One side is in use while the other acts as a reserve. They are equipped with air chambers of ample capacity to steady the pressure and give an even flow of oil to the burners. In addition to air chambers usually attached to the pump there are often auxiliary air chambers placed in the line between the pump and burners. These are charged with air to pressures of 10 lbs. to 20 lbs. Piston rod packing should be of a nature that will not be attacked by oil, as asbestos or metallic.

Pump Governors control the pump action and thus enable it to deliver a steady supply of oil to the burners at uniform pressure.

Strainers may be high or low pressure and are of the duplex type and so arranged that the oil can be passed through either as desired. It is often found advisable to install strainers on the suction as well as discharge side in order to protect the pump.

Heaters are made of steel coils and heavy cast iron or steel shells. The oil passes through the coils and steam through the shell. All coil connections are outside the shell to facilitate repairs. Coils are made of steel rather than copper to better resist the action of high sulphur oils. Heaters are usually in duplicate, one being in use while the other acts as a reserve. A high rate of heat transfer is obtained from double pipe installations similar to those in refrigeration plants, as a 2″ pipe in a 3″ shell. This arrangement eliminates the danger of hidden leaks, as all joints can be seen. Most oil heaters are equipped with drip pans to catch waste oil, and with oil relief valves which operate automatically and relieve excess oil pressure by returning oil to the pump suction. Excess pressure in the heater would occur when the oil valves are closed and steam is on the shell.

Meters are located where desired in the system. They serve as a useful check on other methods of measuring the consumption of oil. Owing to the high temperature of the oil passing through and its composition, such as its sulphur content, meters must be of special design. As an oil meter is calibrated for the average flow through it, a large deviation from this rate may affect the accuracy of the meter so that other methods should be used in conjunction with it for measuring the oil consumption.

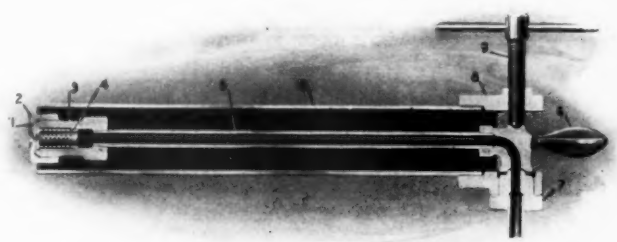
Burner Governors maintain an even boiler pressure and thus tend to decrease the amount of steam used for atomization. In the mechanical burner the boiler pressure controls either the pump pressure or the relief valve at the burner, as in the Peabody burner.

Thermometers of the proper range are located at the burners, at the oil heater outlets and on the pump suction between pump and storage tank. Temperatures are given in F °.

Pressure Gauges of the proper range are located at the burners and at the oil heaters and pumps.

Draft Gauges indicate either the flue draft, the furnace draft or the differential between the two. In the differential draft gauge, the indications are a guide to the amount of air passing through the boiler.

Oil level Gauges keep a constant record of the oil level in all tanks. They are located on the wall near the boilers in plain view of the operator.



Courtesy of White Fuel Oil Engineering Corp.

Fig. 10.—Todd Mechanical Oil Burner. 1. Tip. 2. Nut. 3. Body. 4. Strainer and atomizer. 5. Tube. 6. Handle. 7. Union bushing. 8. Housing. 9. Housing screw. 10. Jacket tube.

Pipes and Fittings are standard or extra heavy to suit the pressures to be carried. The gate type of valve is usually preferred. Long pipe lines outside of buildings, carrying heavy fuel oils, are kept warm by running a parallel steam line in the same trench, or by enclosing the oil line in a larger pipe carrying steam, or by wrapping together the separate steam and oil lines in a non-conducting covering. In

some cases, where the oil lines are unusually long, satisfactory results are obtained by installing small oil heaters at regular intervals in the oil line. The heaters boost the temperature of the oil and prevent it from falling below the desired minimum.

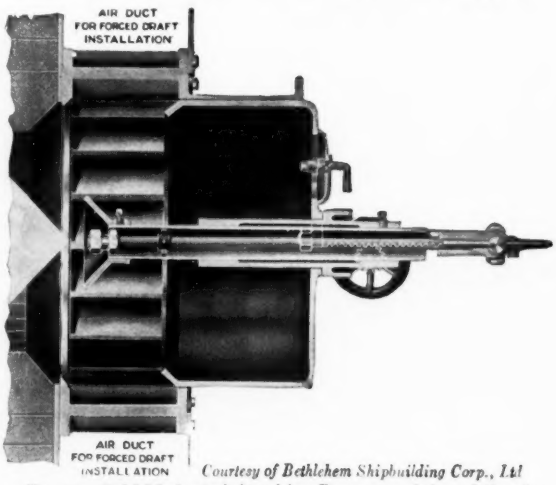
Oil Burners have been described above. The number of burners necessary per boiler depends on the capacity of the boiler and the size and type of burner. This data is furnished by the manufacturer.

The capacity of an oil burner, by which is meant the pounds of oil burned per hour, depends on the size of the orifice and on the pressure, temperature and viscosity of the oil. With orifice and pressure constant, the capacity increases as the temperature rises. The rising temperature lowers the density of the oil and decreases the capacity, but simultaneously the viscosity decreases and increases the capacity at a faster rate. This goes on until a critical temperature is reached beyond which the capacity decreases. The critical temperature varies for different oils and is determined by test.

Combustion

To obtain the best results combustion in an oil-fired boiler should be completed in the furnace before the burning gases strike the tubes or boiler shell. If the flames strike the brick work or tubes, overheating and blistering may occur. The high boiler efficiencies obtainable with fuel oil are due to a minimum amount of excess air passed through the boiler, to lower stack temperature, to smokeless combustion, to better heat transfer from furnace gases to boiler because of higher temperature and to cleaner heating surfaces. The furnace temperature may vary from 2800° to 3200°. The lower value gives better operation as the brick work is saved.

When combustion is going on properly a thin haze should issue from the stack. Black smoke or no smoke means poor combustion. An absolute absence of smoke usually indicates much excess air and low efficiency. The only resistance to be overcome in an oil-fired boiler is due to the tubes and passages; hence only a small draft will draw the necessary air through the boiler. In changing from coal to oil there is often a tendency in the beginning to operate with high drafts. Hence large amounts of excess air are drawn in and low CO_2 readings are obtained. For complete combustion and no excess air the per cent of CO_2 in the flue gases would be approximately 15.5%. CO_2 should range from 13% to 14% which means that there would be only 15% excess air over the chemical requirement for complete combustion. A higher CO_2 percentage means lower excess air with a further probability that not enough air is being admitted to the furnace. Hence CO may be formed and the boiler efficiency will be lower. Therefore, it is best not to aim for too high a



Courtesy of Bethlehem Shipbuilding Corp., Ltd

Fig. 11.—Dahl Mechanical Atomizing Burner, consisting of tip of special design mounted on the end of burner pipe, which extends into furnace front through an adjusting pipe. On the end of adjusting pipe is a cast iron deflector which can be adjusted by moving in or out to position where flame will receive proper amount of air for perfect combustion. Operator can regulate supply of air to burner by adjusting area of air inlet. This is accomplished by a rack and pinion attachment fitted with hand wheel, which operates a movable part of the furnace front to open or close the air inlet.

percentage of CO_2. The maximum percentage of CO_2 in different fuels is approximately as follows:

Semi-Anthracite, 19%
Bituminous Coking 18.8%
Semi-Bituminous 18.8%
Bituminous Non-Coking 18.7%

Hydrogen influences the maximum CO_2 possible with different fuels. The more hydrogen the less CO_2 in the products of combustion.

Advantages of Fuel Oil

Compared with other fuels for combustion purposes, petroleum possesses many distinct advantages which far outweigh any disadvantages. Solid fuels, of course, exist as the greatest competitor to fuel oil. Gas, as fuel, while common to many localities where its production or existence in natural state is prevalent, can

Courtesy of Briggs Engineering Co.

Fig. 12.—Burnwell Mechanical Atomizing Burner, showing tip, burner socket, burner pipe, body, clamp, lever and Tee handle.

not rightfully be considered as a competitor. As compared with solid fuels, however, the economic advantages of fuel oil are general, and will exist wherever the locality involved. From a marine viewpoint they stand forth pre-eminently. Hence they are discussed chiefly from that angle. It is generally agreed by all concerned, today, that marine demands (especially Naval) must take precedence over all others in the fuel oil market.

Advantages in the Marine Service

1. Firing Fuel Oil: the features of general cleanliness, the total absence of ash to be handled, and elimination of danger from spontaneous combustion, are paramount.

2. Practically smokeless combustion is easily attained.

3. Quick and easy bunkering from shore or by lighter, is possible, whatever the weather, by day or night, with no dirt, dust or excessive labor.

4. Labor costs in firing are reduced from 60% to 75% as compared with coal. Stokehold hardships are eliminated. Boiler maintenance costs are reduced and the life of the boilers is materially increased.

5. Steam can be raised in about half the time necessary with coal; fires can be lighted practically instantly; there is no cleaning of fires; far less cleaning of furnaces and flues and very little soot accumulation.

6. Oil can be stored in double bottom or peak tanks, thus eliminating special bunkers. Also, approximately 50% more heating value can be stored in the same volume.

7. Approximately 80% of the heating value of fuel oil is utilized in raising steam, as against about 65% with coal.

8. Lengthy storage of fuel oil is possible far more safely and economically than with coal. Oil does not deteriorate, whereas coal loses from 2% to 10% of its heating value during weathering, and spontaneous combustion is a constant hazard.

Fuel Oil Advantages on the Railroads

1. Increased mileage per loading due to the greater number of heat units that can be contained in a given storage space, is of prime importance.

2. There is little smoke—a great advantage in passenger service.

3. Practically no sparks are developed to cause firing of bridges, cross-ties, timberland, grainfields, etc.

4. Considerable time is saved in preparing a locomotive for the road; there is no ash to be handled and less damage results to arch and flues.

5. Labor costs are decreased in loading and manual effort in firing.

6. No fires require banking when coasting on down grades. Thus the fuel consumption may be decreased or stopped altogether according to the steam pressure the fireman is carrying. With coal, even under banked fires, fuel is consumed to a considerable extent.

Stationary Boiler Plants

Practically all of the advantages that fuel oil possesses over coal as reviewed under "Marine Service" hold in the stationary boiler plant. Certain other specific points are:

1. Tank storage in any convenient place is possible, with no loss, waste, dust or dirt; and with little extra cost.

2. Fuel oil enables peak loads to be met far more promptly and with practically no boiler strain up to reasonable limits.

3. Fuel oil can be efficiently fired with only about 15% to 20% of excess air. Therefore minimum variation in furnace temperatures is possible, and heat losses in the waste gases are reduced. Fires can be more easily controlled with practically smokeless combustion.

NOTE: As compared with gas, the advantages of fuel oil are more strictly of a combustion nature. Storage and handling principles remain practically similar but of course greater storage space is required for gas. Primarily fuel oil eliminates a certain fire hazard that always exists where gas is used. Gas leaks are apt to be far more serious to the plant and operators

than fuel oil leaks, due to the suffocating properties, inflammability and difficulty in locating.

Another distinct advantage of fuel oil over gas as a boiler fuel is the practical absence of unburned gas accumulations in the last pass or uptake of the boiler. For this reason, firemen using gas will always tend to open the stack or uptake dampers too wide. As a result the back draft is increased and a consequent reduction of the CO_2 percentage and boiler efficiency is obtained, allowing considerable unburned gas to pass up the stack.

For Industrial Purposes

The advantages of fuel oil in this regard will depend largely on the type of work. The principle involved is simply that of heat production for use as heat directly. The chief specific advantages over solid fuels such as coal or coke are:

1. Higher temperatures are obtainable and greater ease, flexibility and range of regulation is possible.

2. There is almost an entire absence of soot in dust chambers, etc.

3. Increased capacity of furnaces and decreased storage and handling space necessary results.

NOTE: As compared with gas fuel for such purposes, i.e., producer gases, etc., fuel oil possesses few advantages except as to the fire hazard element and less storage space, already discussed above.

Household Heating Fuel

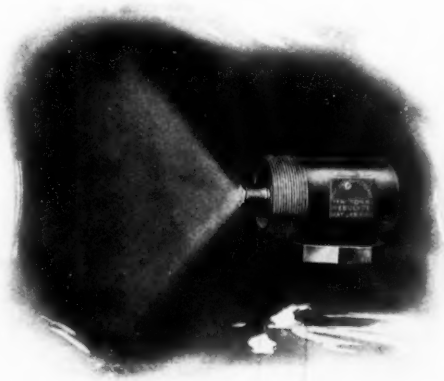
In this respect fuel oil has already been discussed, its relative merits, etc., being fully considered.

Conclusion

The fuel oil question has been reviewed briefly above, from all angles, covering equipment, methods of firing and the specific advantages which hold true in the various fields of usage. Of its desirability as compared with other fuels there is no doubt. However, in coming to a decision as to whether fuel oil or coal* should be burned, an intensive study of pertaining local conditions should be made. Such a study should be based comparatively on the entire cost of operation, preferably over a year's time, and including seasonal and other variations. In detail these are:

1. Cost of fuel delivered at the plant.
2. Loss of fuel in transit.
3. Depreciation of fuel in storage.
4. Cost of handling, transferring and firing.
5. Maintenance and operation of stokers and stoker machinery.
6. Cost of furnace upkeep, to include firing tools, grate repairs and renewals, etc.
7. Cost of ash cans, conveyors and other ash handling machinery.
8. Cost of carting and disposal of ashes.
9. Waste of fuel in cleaning and banking fires.

If the total steam made during the year is known, the evaporation per pound of coal can be obtained for the period and from this figure the oil-equivalent for coal calculated as shown in Example No. 5 in the appendix to this article. If this information is not available, either the boiler efficiency or the evaporation should be determined by test, and the oil-equivalent may then be calculated as shown in Examples 5 and 6.

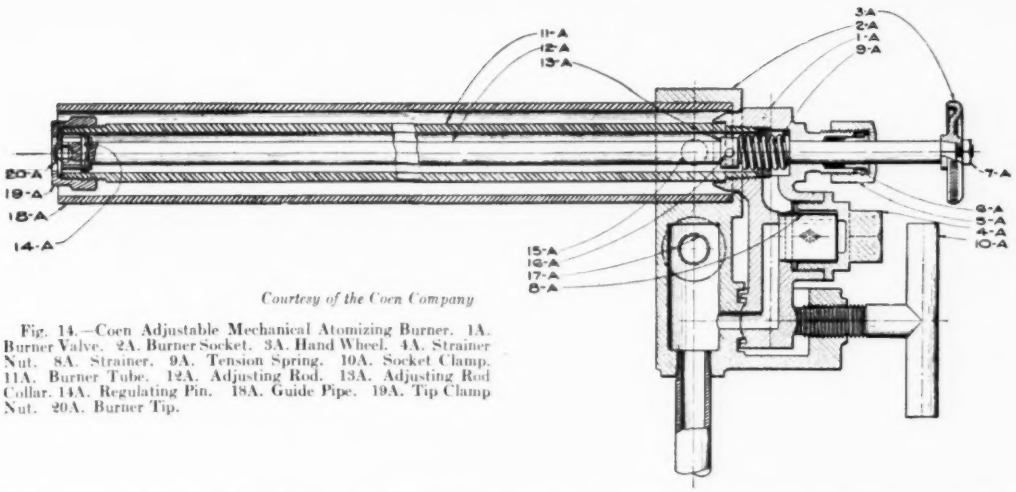


Courtesy of The Anthony Company

Fig. 13.—Anthony Nebulyte Burner, showing spray obtained by forcing oil under moderate pressure through especially designed tip. Air for combustion is admitted through pipe around oil nozzle.

To obtain the oil-equivalent of the coal burned in any given plant, the loss of fuel in cleaning and banking fires must be known. This loss varies from 10% to 20% of the coal consumed. The oil required per annum is consequently obtained by basing calculations on 80% to 90% of the yearly coal consumption, and using the oil-equivalent of coal, calculated as indicated above. The cost of oil per annum is then calculated, and by adding the estimated cost of boiler room labor the cost of oil opera-

*No discussion relative to burning of gas is considered since the ability to obtain same will be purely restricted to isolated localities, where an excess of natural or producer gas is prevalent.



Courtesy of the Coen Company

Fig. 14.—Coen Adjustable Mechanical Atomizing Burner. 1A. Burner Valve. 2A. Burner Socket. 3A. Hand Wheel. 4A. Strainer Nut. 8A. Strainer. 9A. Tension Spring. 10A. Socket Clamp. 11A. Burner Tube. 12A. Adjusting Rod. 13A. Adjusting Rod Collar. 14A. Regulating Pin. 18A. Guide Pipe. 19A. Tip Clamp Nut. 20A. Burner Tip.

tion per annum is readily obtained and compared with the cost of coal operation as determined in accordance with the suggestions given above.

Having derived comparative costs of oil vs. coal, based on the above details, the next step would be to study conditions upon which fuel delivery would hinge. We all will agree that fuel oil is the ideal fuel for combustion purposes—with certain provisos: i.e., that it can be obtained at a price that will enable it to compete economically with coal; and that delivery at this price is an assured fact. In brief, the user or prospective customer must be reasonably sure of these two points.

The engineer, therefore, should investigate his source of supply thoroughly and be certain that he does not tie up with some marketer whose ability to live up to his agreements is not established. Too often also irresponsible sellers of equipment make claims for their apparatus that can not be substantiated.

The failure of the supplying agent to make deliveries and the unsatisfactory performance of unproven apparatus often give the consumer an unwarranted impression that oil burning is full of hazards. If, however, the buyer deals strictly with reputable well-established producing and manufacturing companies, there will be no such failures and the burning of fuel oil will prove to be one of the most important factors in the economical and efficient operation of the plant.

FUEL OIL MEASUREMENTS
(11° to 35° Be.)
CURVE SHOWING FACTORS FOR CORRECTING VOLUME MEASUREMENTS AT ANY TEMPERATURE TO VOLUME AT STANDARD TEMPERATURE OF 60° F.
CO-EFFICIENT OF EXPANSION USED FOR PLOTTING CURVE .0004 PER DEGREE F.

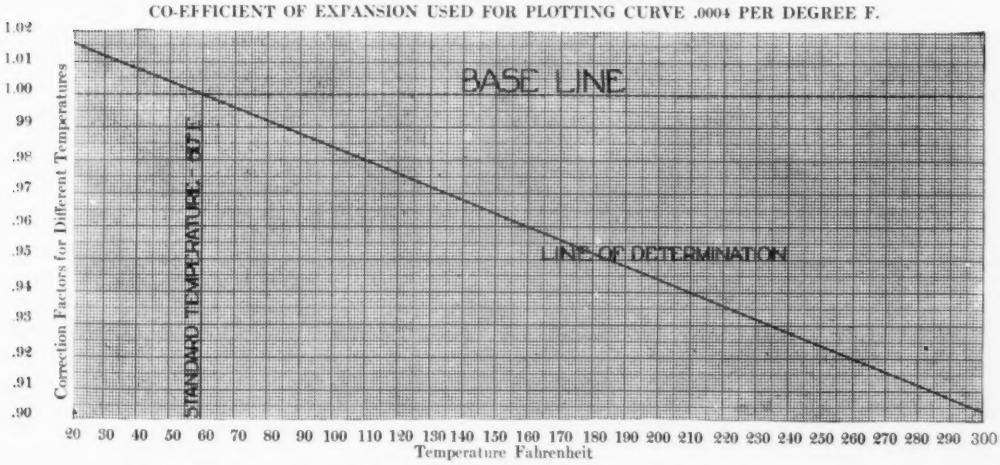


Chart 1.—To obtain the volume of oil in gallons or barrels at 60° F. multiply the actual volume at any temperature by the factor for that temperature as determined by the above chart. For example: assume a measurement of 5,000 gallons or barrels made at 100° F. The factor for this temperature as obtained from the chart is .984. Multiply 5,000 x .984 and obtain 4,920, which is the volume in gallons or barrels at the standard temperature of 60° F.

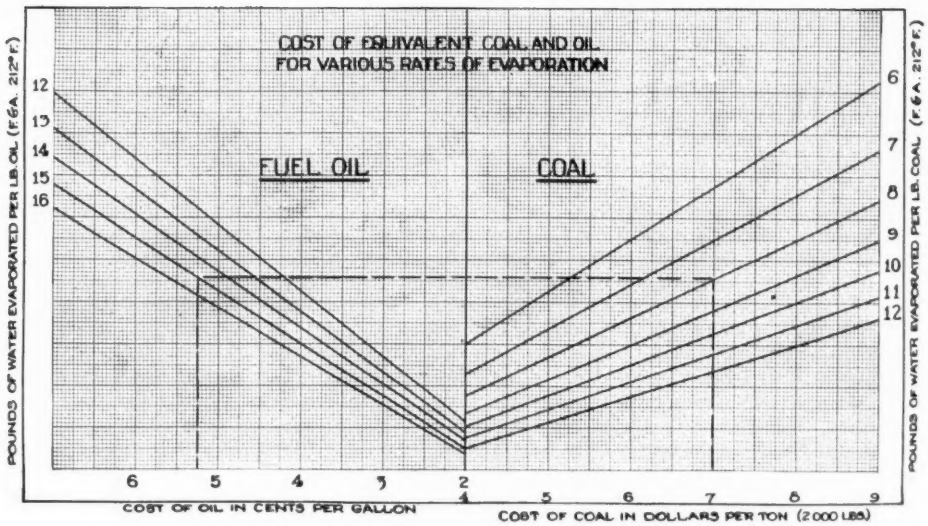


Chart 2.—Illustration of use of chart: assume coal to cost $7.00 per ton and the evaporation from and at 212° F. per lb. of coal to be 8 lbs. water, and per lb. of oil to be 15 lbs. of water. Begin at Fig. 7 under "Coal" and follow dotted line up to 8 lb. line; then follow across to the 15 lb. line under "Oil" and down vertically to the base line, and obtain 5.25¢ per gallon as the equivalent cost of oil.

Miscellaneous Fuel Calculations

1.

Oil Necessary per hour to Develop Boiler H. P.

Given: Latent heat per 1 lb. of steam.....=970.4 B.T.U.'s
Evaporation of water from and at 212° F. per B. H. P. per hour.....=34.5 lbs.
Heat Units in one pound of oil.....=18,300 B.T.U.'s
Efficiency of Boiler.....=80%
∴ B.T.U.'s required per B. H. P. hour.....=34.5 x 970.4

Oil required per B. H. P. hour $=\frac{34.5 \times 970.4}{18{,}300 \times .80}=2.2.8$ lbs.

Gallons of oil $=\frac{2.2.8}{8}$.....=2.86 gals.

Steam per B. H. P. hour for Steam Atomizers =0.3 x 22.8=6.84 lbs.

2.

Evaporation per lb. of Oil under Given Boiler Conditions

Given: Steam Pressure.....=150 lbs.
Feed Water Temperature.....=200° F.
Heat in lb. of steam at 150 lbs. gauge pressure=1,193.5 B.T.U.'s
Boiler Efficiency.....=80%
Heat in lb. of feed water (200-32).....=168 B.T.U.'s
Heat required to form 1 lb. of steam at 150 lbs.....=1,025.5 B.T.U.'s
Heat available per lb. of oil=.80 x 18,300..=14,640 B.T.U.'s
∴ Evaporation per lb. of oil, under the above conditions $=\frac{14{,}640}{1025.5}$.....=14.3 lbs. of water

3.

Actual Evaporation Changed to Evaporation from and at 212° F.

Given: Steam Pressure.....=150 lbs.
Actual Evaporation per lb. of Fuel.....=7.5 lbs.
Feed Water Temperature.....=200° F.
From Problem 2, Heat required to form lb. of steam, under the given conditions.....=1025.5 B.T.U.'s
∴ Evaporation from and at 212°F.$=\frac{1025.5 \times 7.5}{970.4}$=7.9 lbs. water

4.

Boiler Efficiency Calculated from the Evaporation

Given: Latent heat of steam.....=970.4 B.T.U.'s
Heat value of coal per lb.....=11,000 B.T.U.'s
Evaporation of water from and at 212° F.....=8 lbs.
∴ Boiler Efficiency $=\frac{8 \times 970.4}{11{,}000}=.705$ =70.5%

5.

The Oil-Equivalent of Coal Calculated from the Evaporation

By the Oil-Equivalent of a given amount of coal is meant the quantity of oil that will evaporate the same amount of water under the same boiler conditions.

Given: Evaporation of water from and at 212° F. per lb. of coal.....=8 lbs.
Evaporation of water from and at 212° F. per lb. of oil.....=15 lbs.
Weight of Oil per gallon.....=8 lbs.
∴ Oil-Equivalent of a ton of coal $=\frac{2{,}000 \times 8}{15 \times 8}$.....=133.3 gallons

6.

The Oil-Equivalent of Coal Calculated from the Boiler Efficiency

Given: Boiler Efficiency with coal.....=65%
Boiler Efficiency with oil.....=80%
Heat value of coal per lb.....=11,000 B.T.U.'s
Heat value of oil per lb.....=18,300 B.T.U.'s
Weight of oil per gallon.....=8 lbs.
∴ Oil-Equivalent of 1 ton of coal $=\frac{2{,}000 \times 11{,}000 \times .65}{8 \times 18{,}300 \times .80}$=122 gals.
If the heat value of coal is 14,000 B.T.U.'s per lb., the Oil-Equivalent calculated as above.....=155 gallons

To calculate the heat value of oil from its Baume gravity, the following equation is accurate enough for practical purposes:

B.T.U.'s per lb.=18,650+40(Be.gr.—10)

To change Specific Gravity into Baume degrees or vice-versa use the formula:

$$\text{Sp. gr.}=\frac{141.5}{(131.5+\text{Be.deg.})}$$

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Check up

Try to form a mental picture of the company which is selling you lubricants. Check items on blank below.

Are you buying from a company which—

YES	NO	
☐	☐	1. Is entirely dependable?
☐	☐	2. Has a wide choice of crude?
☐	☐	3. Controls every process of refining, handling and manufacture?
☐	☐	4. Has adequate and efficient shipping facilities?
☐	☐	5. Handles products from well to purchaser?
☐	☐	6. Which has thousands of tank cars on all the railroads of the country?
☐	☐	7. Maintains warehouses at all important centres?
☐	☐	8. Fleet of motor vehicles for local delivery?
☐	☐	9. Huge stocks of lubricants of all kinds on hand at all times all over the country?
☐	☐	10. Are the oils of high grade, of constant quality, fully able to meet your varying requirements?
☐	☐	11. Can the seller supply all your lubricating needs, and also your burning oils?
☐	☐	12. Can the seller supply you with unstinted engineering service through experienced and capable lubricating engineers?

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If there are a number of "No's" it will pay you to investigate what The Texas Company offers—for the above is a skeleton of some of the things which are earning a very high regard for Texaco lubricants in all lines of industry.

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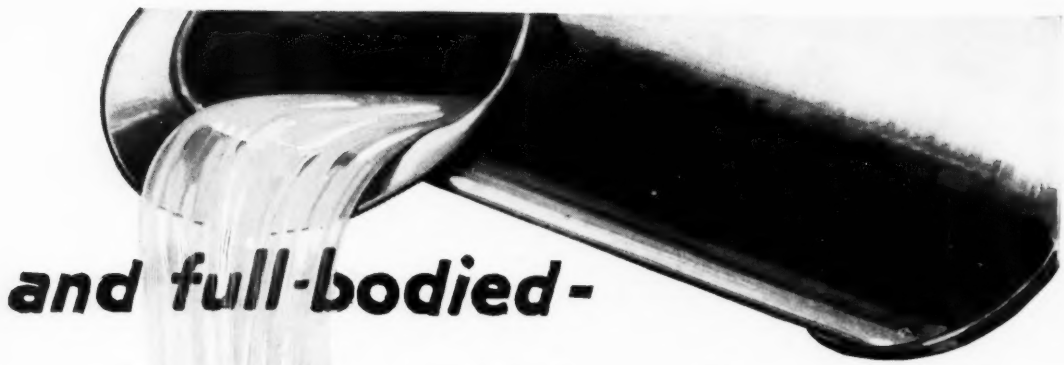

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